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A SHORT SUMMARY

OF THE

GEOLOGICAL HISTORY OF ANGLESEY

BY

EDWARD GREENLY, D.Sc., F.G.S.

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A SHORT SUMMARY OF THE GEOLOGICAL HISTORY OF ANGLESEY.[1]

By EDWARD GREENLY, D.Sc., F.G.S.

PART I.—GENERAL CONSIDERATIONS.

Introductory.

There is no district of its size, even in the British Isles, combining such variety of composition with such complexity of structure as that which has, in geologically recent times, taken shape as Anglesey. The paramount interest of the Island lies in its ancient metamorphic or altered rocks, whereof it contains the largest and most diversified emergence that is found in southern Britain; but its long geological record is full of many other fascinating subjects.

The reader is, nevertheless, requested to bear in mind that this essay is an attempt to condense a very great subject, and by no means an easy one, into a very small space, which leaves but scant opportunity for explanations and definitions. Certain vital principles, indeed, are expounded, and a glossary of terms is given, to which readers should turn if they meet with any expression which is unfamiliar to them.[2] The same limitation of space, moreover, compels me to make statements on several difficult subjects in an unqualified and somewhat *ex cathedra* manner. The evidence for these, and the due qualifications, will be found in the new Geological Survey Map of and Memoir upon Anglesey, copies of which, through the generosity of the President, are in the library of the Anglesey Antiquarian Society.

Anglesey a Thing of Yesterday.

To grasp the general principles of Geology requires hardly more than sound commonsense and a little application, so that exposition of past geological history would present no serious difficulty but for one circumstance. This is, that such changes in the configuration of hill and valley, land and water, as take place during the life-time of any one man, are seldom noticed, and so the topography which we know comes, insensibly, to

[1] Copyright by E. Greenly.

[2] Any reader who wishes to become better acquainted with geology and its varied and extensive problems is recommended to provide himself with Prof. W. W. Watts's "Geology for Beginners" (Macmillan, price 3*s*. 6*d*.), a book which treats of the subject in a manner concise as it is lucid.

be regarded as permanent. Consequently, when we first attempt to trace out the geological history of a district, we are apt to assume that the familiar features were present all along.

Now, before we can interpret the geology of Anglesey or, indeed, of any country, this illusion must be totally abandoned. A land-surface is the subject of unremitting waste. Attacked by the gases of the atmosphere, which are dissolved in the rain, the rocks decay, and their dust and fragments, washed down into the rivers, are eventually swept out to sea. The rivers, ever cutting down and widening their channels, leave the intervening masses to stand out for ages as hills or mountains, which, nevertheless, are eventually doomed to succumb as well. In the end, the whole region must (unless elevation recur) be reduced to a plain, and its wreckage laid down as sediment upon the sea-floor. No land-surface, therefore, can have existed for more than a short fraction of geological time.

Reading, for example, that marine shells are found in the rocks of such a hill as Bwrdd Arthur, we may say to ourselves, "Then Anglesey must have been beneath the sea." But when those shells were living, there was no "Anglesey," there was no Britain; the geography of the European area, nay, of the entire world, was quite different from what it is to-day. In fact, the great rock-formations of the Island convey an intelligible story only when we thoroughly realise that they were all accumulated under geographical conditions which have long since vanished.

We shall therefore speak, when dealing with events of the past, not of "Anglesey," but of "our Area," till we come to treat of that period, ancient indeed in years, but geologically recent, known as the Pliocene, when the term "Anglesey" first acquires a meaning.

Nature and Origin of the Leading Types of Rock.

In a geological study of any district, we first endeavour to determine the nature, origin, relative age, and structural relations of its component rocks, and secondly to infer therefrom the successive geographical conditions which they indicate, and the processes whereby the existing land-surface has been sculptured out of them. These rocks may be either igneous, sedimentary, or metamorphic, and members of all these classes are found in Anglesey.

Those termed igneous have consolidated from a molten state, and most of them are crystalline. When poured out as lava from volcanic vents, this consolidation takes place on rapid cooling in the open air or on a sea-floor, and so the crystals are usually small. In such eruptions, moreover, much of the lava may explode on ejection into dust and fragments, which,

scattered far and wide, form beds of so-called volcanic "ash." But if the molten rock fail to reach the surface which existed at the time, it cools much more slowly deep underground, giving opportunity for the growth of larger crystals, as in the granites, and other members of what is known as the "plutonic" type.

The sedimentary rocks, which have a stratified arrangement, are composed of the débris of old lands, carried by running water to old seas, on whose floors they were deposited as beds of shingle, sand, or mud, which gradually harden into conglomerate, sandstone, or shale. Rocks of this kind may contain "fossil" remains of long extinct forms of plant and animal life, some of them, in fact, such as limestones, flints, and coals, being largely composed of such remains.

Metamorphic or altered rocks may be members of either the igneous or the sedimentary class, which, owing to slow movement under heavy pressure and the consequent high temperature, have undergone recrystallisation.

Disturbances.

That the bedding of sedimentary rocks must have been horizontal when deposited is obvious. The disturbances ever proceeding in the earth-crust, however, rarely permit them to remain so, but throw them into curves and even into folds of various magnitudes and various inclinations, which may be ruptured locally by "faults" and "thrusts." For such brittle substances as rocks to fold is manifestly impossible at or near the surface, and yet we know that, in most cases, they were as "hard" when folded as they are to-day. But consider the case of any portion of rock at a considerable depth. The overlying weight is far greater than would suffice to crush it, yet, being supported on all sides, it cannot crush, and consequently becomes plastic and pliable. The folded rocks which we actually see must, in fact, have been deeply buried at the time of their disturbance; the overlying masses having since been swept away by denudation or waste. In Anglesey, horizontal beds are hardly to be seen, and the inclinations are very varied, often with rapid changes of angle, and indeed great complexity of curvature.

Sequence of Events in Time.

The sedimentary rocks furnish geological science with the idea of an orderly succession of events in *Time*. For this purpose, they have been divided into a series of "*Systems*" or major formations, corresponding to as many principal successive periods. A table of them, arranged on the page in ascending order from the oldest upwards, is given below. Every system is

not found everywhere, and so those which are represented in Anglesey by some rock-formation are marked with an asterisk.

GROUPS OF SYSTEMS.	SYSTEMS.
NEOZOIC	Holocene.* Pleistocene.* Pliocene. Miocene. Oligocene.* Eocene.
MESOZOIC	Cretaceous. Jurassic. Triassic.
PALAEOZOIC	Permian.*? Carboniferous.* Devonian.* Silurian* Ordovician* Cambrian* ?

* PRE-CAMBRIAN SYSTEMS.

The systems are defined, not by the nature of their component rocks, which may be different in different districts, but by the characters of their organic remains or "fossils." By this means, formations which occur in widely separated parts of the world can be correlated with each other. We find, for example, in America, beds containing a fossil assemblage like that of the Ordovician of Wales, and moreover that they are underlain, as in Wales, by beds with a fossil assemblage of Cambrian, and overlain by beds with an assemblage of Silurian type. The same principle, carried into minute detail, has lately enabled us to subdivide several of the systems into "Zones" characterised by the presence of some particular species which is confined to the Zone. Thus, from the evolutionary point of view, a system is composed of the rocks which were formed during the development and disappearance of a whole fauna and flora; while a zone is composed of the rocks formed during the evolution and dying-out of a single species.

The systems, in their turn, fall into three great natural groups, according to their general types of life. Those of the Palaeozoic (from the Greek palaeo —— ancient, zoe —— life) are the most primitive and remote in character; those of the Mesozoic (meso —— middle) of an intervening character; those of the Neozoic (neo —— new)[1] begin to be of modern types. Every Palaeozoic and Mesozoic species is extinct; and so are many of

[1] Often called Cainozoic (kaino = new).

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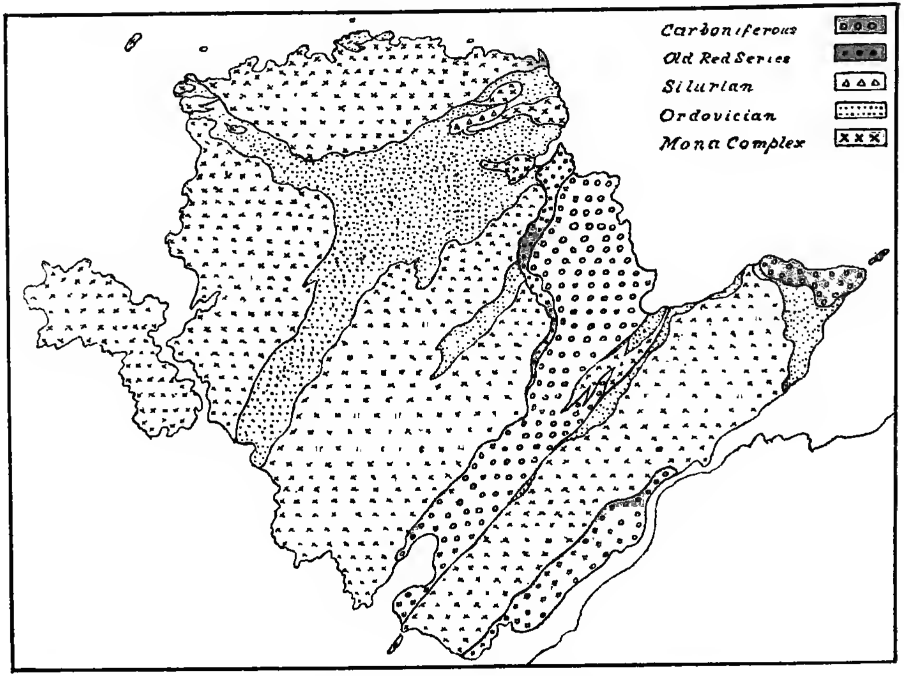

GEOLOGICAL MAP OF ANGLESEY.

Greatly generalised and simplified.

Scale: 1 inch = 6 miles.

the Neozoic, but a few still existing species appear in the first system of that group (the Eocene), increasing in proportion until in the Holocene all the species are still-living forms.

Below the base of the Cambrian system, fossils are rare and seldom well preserved. Consequently, although five or six Pre-Cambrian systems are now known (and there may be as many more) we have as yet no means of correlating those of one country with those of another. Even within the limits of a single country, moreover, our difficulties are enormously aggravated by the complex disturbances and metamorphism which these ancient rocks have often undergone.

Access to the Older Rocks.

That we have access at all to the older systems, as well as to plutonic and metamorphic rocks (whose crystalline characters

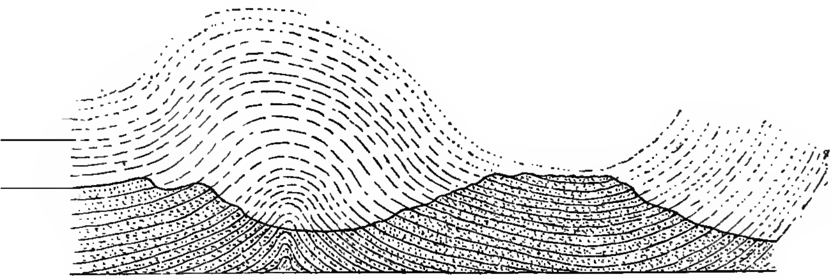

FIG. 1.—IDEAL SECTION SHOWING SCULPTURE OF A LAND-SURFACE OUT OF FOLDED BEDS AND EXPOSURE OF OLDER ROCKS BY EROSION.

could only have been developed at great depths) is due to the combined effect of disturbance and of sub-aerial denudation. In the course of slow folding, it is evident that certain tracts must be raised (Fig. 1). Their upper parts then becoming exposed to sub-aerial waste, are gradually washed away. Thus: the ancient rocks of their lower parts, once deeply buried, are, by removal of the overlying cover, laid bare to view.

Such a tract is Anglesey, a kind of natural sky-light opening, where we enjoy the opportunity of access to formations which, for hundreds of miles around, lie deep beneath our feet.

PART II.—HISTORICAL.

We shall now consider the Geological history of our Area, system by system, beginning with the oldest, or Pre-Cambrian. The reader may follow the present-day distribution of the rocks belonging to the several systems by means of the coloured map.

THE PRE-CAMBRIAN PERIODS.

The Mona Complex.

Introduction.—Of the old formations thus laid bare in our Island, the most ancient is that of the metamorphic or altered rocks already alluded to, which have been provisionally termed "The Mona Complex." They may be regarded with confidence as of Pre-Cambrian age, an expression which implies an antiquity too vast for the mind to realise. The Complex appears to comprise at least two distinct systems; it is composed of 70 different types of rocks; and the structures are involved in the extreme. Accordingly, the following account of it must not be expected to be easy reading, being an attempt to present, in simplified form, some of the results of one of the most advanced lines in geological research. Yet, without such attempt, some two-thirds of the Island, and those its most interesting parts, would be a sealed book, and it would hardly have been worth while to write this essay at all.

Its oldest member.—The record opens with the development of certain crystalline rocks whose mode of origin is imperfectly understood, except that they could only have been formed at great depths, under high temperatures and pressures. They are "Gneisses," that is, they are more or less granite-like in texture, but with a lenticular or banded arrangement, and they present the highest-known grade of crystallisation. They constitute the *first* of the two systems included in the Complex.

Its Bedded Succession and its Volcanoes.—After an unknown interval, there comes a time when we are able to form a vague picture of the conditions. Prolonged erosion had laid bare the ancient crystalline rocks, and upon a surface partly composed of them, volcanoes were pouring out lavas and ejecting dust. Then ensued subsidence, and our Area became part of a wide, though shallow, sea-basin. This basin went on sinking for an immense period, but never became deep, for all the while it kept on filling up with sediments. In and around it, volcanoes broke out at four more intervals, so that their lavas and dust became interbedded with the marine sediments. Thus was accumulated a Bedded Succession, whose thickness is estimated at 20,000 feet, and of which most of the visible part of the Mona Complex is composed.

The sediments were once ordinary sandstones, shales, and limestones, with thin carbonaceous and flinty beds; and some of them have yielded casts of sea-worms and remains of lowly sponge-like organisms. The volcanic products include several different kinds of lavas and ashes; among the lavas being a variety rich in sodium, known as spilites, with a singular structure like pillows piled on one another, which has lately been found to be produced when molten rock flows out and consolidates upon a sea-floor. The Bedded Succession constitutes the *second* of the two systems which are included in the Mona Complex.

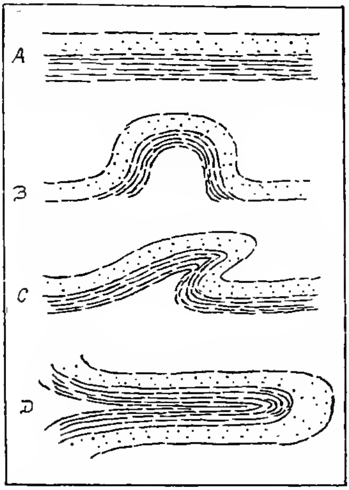

FIG. 2.—DIAGRAMS OF FOLDING.

A. Unfolded strata. C. Over-driven fold.
B. Normal fold. D. Recumbent fold.

It was subsequently invaded from below by another series of injections of molten matter, which, however, did not reach the surface of that time, but crystallised deep underground into plutonic masses. They have a range of composition from serpentine (which has a low percentage of silica and high percentages of magnesium, lime and iron) to granite (which has a high percentage of silica and low percentages of magnesium, lime and iron). One of them is eleven miles in length, and, in fact, their importance is such that they should be regarded as a *third* member of the Mona Complex.

All these rocks, however, have undergone some degree of metamorphism, usually obscuring and sometimes obliterating their original character. Its causes and effects will be considered later on.

Its Great Disturbances.—At last, after the deposition of the Bedded Succession, the long subsidence came to an end, and disturbances, due to impulse in an approximately horizontal direction, set in on a stupendous scale—of the highest order, in fact, that is known to science. The formation was gradually doubled over on itself more than once in what are now termed "recumbent folds," whereon the over-folded parts over-ride the lower ones almost horizontally (Fig. 2). Indeed, the most extraordinary feature of the Complex is that, over something like half its visible extent, the original order of superposition of the beds has been turned upside down. These recumbent folds cannot be seen as such anywhere in the Island.[1] They are far too large, and are known only by inference.

After their production came a pause, and then it was that the deep-seated igneous rocks were intruded into and across the folded beds (see p. 3). This pause over, the impulse was resumed, and the huge recumbent folds were in their turn buckled up into great secondary folds.[2] A few of these *are* directly visible as folds, near the South Stack, Holyhead, where they can be seen to sweep up and down more than 400 feet of cliff. The major secondary folds were in their turn corrugated into minor folds (Fig. 3, and diagrammatically indicated in Plate II by crinkling) of a few feet or inches in length, visible at innumerable crags; and those, finally, into minimum folds which are discernible only under the microscope!

All four orders of fold are locally ruptured along planes of over-thrust, which in some parts become so numerous as to obliterate the minor folding and tear up the rock, so that for miles together we can see nothing but overlapping lenticular strips (Fig. 4).

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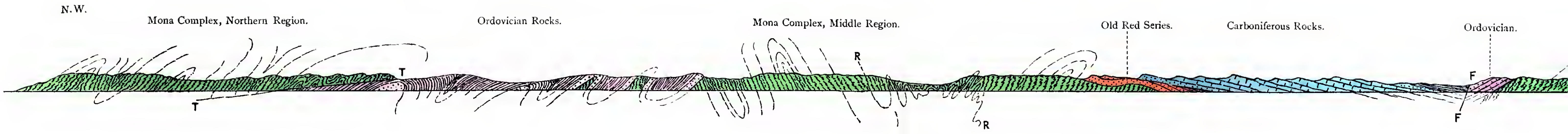
[1] Nor can they be shown in the Section, Plate II. See next foot-note.

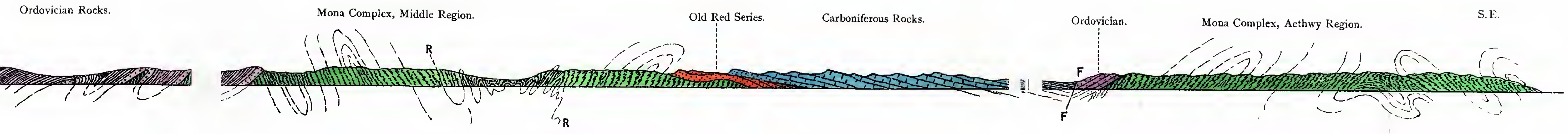
[2] A model will show this better than any figure. Let the reader place a hearth-rug on a table; and laying hold of one end, pull it until it comes exactly over the other end, thus doubling the rug on itself. That is a recumbent fold. Then, placing one hand where the two ends have come together, and the other hand where the rug turns over, slowly push his hands towards each other. The recumbently folded rug will buckle into a series of secondary folds. A few of those of the Mona Complex are shown in the Section, Plate II. The broken lines above the surface of the land, added to elucidate the structures, represent portions of the great secondary folds which have been removed by waste, in the manner explained on p. 2 and in Fig. 1. Though the recumbent folding cannot be shown as such in this section, it may, perhaps, be remarked that the portions of the Mona Complex to the left of the line RR, belong to one recumbent fold and are upside-down; while those on the right of that line belong to the next overlying recumbent fold and are not upside-down. Even if this statement does not appear easily intelligible, it will at any rate serve the purpose of giving some faint idea of the extraordinary complexity of the structures of this wonderful formation.



GEOLOGICAL SECTION ACROSS ANGLESEY FROM NORTH-WEST TO SOUTH-EAST.

Highly generalised and simplified.

Horizontal scale, about 1 inch = 1 mile. Vertical scale about 3 times horizontal. Base line—sea level.



GEOLOGICAL SECTION ACROSS ANGLESEY FROM NORTH-WEST TO SOUTH-EAST.

Highly generalised and simplified.

Horizontal scale, about 1 inch = 1 mile. Vertical scale about 3 times horizontal. Base line—sea level.

Its Metamorphism.—At lower depths, the rocks were unable to break up, yet they were unable to resist, and were modified by the tremendous forces alluded to in a more subtle and indeed more thorough-going manner. They gave way internally, their component minerals being flattened as if they had been passed under a gigantic roller, so that a new series of divisional planes was developed, parallel to the direction of flattening.

From this, moreover, great heat ensued, so that chemical re-actions and re-crystallisation took place along the new planes, the resultant structure being known as foliation or schistosity. The rocks thus metamorphosed are crystalline, with a more or less

FIG. 3.—MINOR FOLDING IN MONA COMPLEX. NEAR PENMYNYDD.
Height about 2 ft.

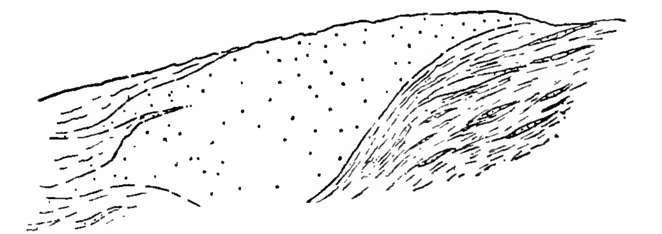


FIG. 4.—DISRUPTION OF BEDS IN MONA COMPLEX. LLANSADWRN.
Height about 2 ft.

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parallel structure, and a marked tendency to split along the folia-tion-planes, which are lustrous and often even sparkling. Sometimes the original igneous or sedimentary textures have escaped this transformation ; but in most cases they have been partially, and over large tracts completely, obliterated. Many varieties of such products are known in the Island, the most extensive being micaceous, chloritic, and hornblendic schists (so-called from the mineral dominant in each) ; a pale green tint, mainly due to the chlorites, being extremely prevalent. A unique feature is an extensive development of the beautiful blue sodium-hornblende known as glaucophane, a mineral not yet found elsewhere in the British Isles.

Thus, it is by reason of these wonderful disturbances that the Complex has become so fascinating a subject of study. To these it owes its labyrinthine intricacy of structure; and to the partial transformation of their energies into chemical readjustments it owes its beautiful crystalline metamorphism.

Its Vanished Mountain-Chain.—Finally, these disturbances are of the same nature as those which have (in the vastly later Miocene period) built up the huge mountain range of the Alps; and there can be no doubt that, in remote Pre-Cambrian times, a tract, whereof Anglesey is but a little fragment, must have been similarly ridged-up into a mountain-chain as lofty as, perhaps loftier than, any which exist to-day. But even while it rose, and for long after, it was the subject of unceasing waste, until, ages untold ago, it was levelled with the sea. Not a feature of it has survived, the surface of the Complex upon which we walk to-day being but a many-times worn down wreck of some of its foundations.

The Cambrian Period.

In view of the great thickness (5,000 feet in Carnarvonshire, and 13,000 feet in Merionethshire) of the Cambrian rocks of the mainland, it is surprising that no certain traces of that system have been identified in Anglesey. There is, indeed, reason to suspect that an attenuated sheet of such rocks was deposited over our Area, but swept away by pre-Ordovician denudation. For an Anglesey geologist, however, the great event of the Cambrian period was the destructive erosion of the mountains of the Mona Complex, whose ruins, carried southward into the sea, went to build up the vast marine deposits of that period; out of which many of the present mountains of the mainland have been sculptured many ages afterwards.

The Ordovician Period.

At the dawn of Ordovician times, we find the Mona Complex again laid bare, and the wreck of its mountain-chain reduced, in our Area, to a plateau some 3,000 feet in height, with deep valleys opening into a western sea. Then subsidence began, and while the sea slowly encroached, its breakers rolled blocks of rock as much as 4 feet in diameter into rounded boulders, and gradually filled the valleys with enormous accumulations of conglomerate, whose beds were laid down upon the worn and upturned edges of the folded rocks of the Mona Complex, from which, moreover, the pebbles were derived. The sandstones, which represent the quieter episodes of this process, contain various marine fossils. At last, even the surface of the plateau sank beneath the waves, whereupon the type of sedimentation

changed to that which is characteristic of an open sea. Layer after layer of dark fine shale was slowly deposited with remarkable regularity over wide areas, until no less than 3,000 feet of them had been laid down upon the sinking floor.

These shales contain a most interesting evolutionary record. They have yielded (besides other fossils) 82 species (the specimens numbering several hundred) of the extinct marine organisms known as Graptolites; which are delicate rows of closely-set cells, each cell having once been inhabited by an animal similar to the sea-anemones of to-day, but rarely so much as an eighth of an inch in length. As we pass from the bottom of the shales to the top, species after species die out and are replaced by others, enabling us to trace the evolution of the Graptolites throughout the period. Moreover, there are a number of zonal species (p. 4). The Ordovician system has been divided into 13 Graptolitic zones, and nine of these have been identified in Anglesey; so that, in spite of the likeness of one shale to another, and of their complex disturbances, it has been possible to make out the true chronological order of the whole series.

The Silurian Period.

Open-sea conditions, with subsidence, continued to obtain, and so the Silurian system is also represented by dark fine shales, containing Graptolites of a still later stage of evolution. Of the 21 zones of this system, only the eight lower ones have been found in Anglesey, and even these are preserved at only one place, though they must have been deposited over the whole of our Area, and indeed far beyond. Probably their successors were also deposited but swept away by denudation.

A Subterranean Volcanic Episode.

Volcanic activity had broken out again, in the region to the south, as early as Ordovician times, for between the sediments of that age in Carnarvonshire and Merionethshire there are thick beds of lavas and ashes. But in our Area there is no trace of them. All seems to have been quiet here until the close of Silurian times. Then there was a re-awakening, and molten rock was injected from below into hundreds of fissures, most of which trend north-west and south-east. These injections, however, did not quite reach the surface of that time to flow out as lava from open volcanic craters, but cooled and consolidated underground; though not at such depths as the "plutonic" intrusions of the Mona Complex. Laid bare by denudation, they now emerge upon the present surface as the long narrow bands known as "dykes." The great majority of them are composed of the heavy dark rock known as dolerite; but there

is a wide range of composition, and many contain a quite different material which is very light in tint. An exceptional and beautiful variety, allied to the dolerites, is mainly composed of large and lustrous crystals of a dark hornblende.

The Post Silurian Disturbances.

This volcanic episode was a prelude to another great series of disturbances which, before the injections had quite come to an end, set in again, of the same type as, and on a scale second only to, those of the Mona Complex. The Ordovician and Silurian rocks, with their underlying floor, were thrown into great and complicated folds, as shown in the section, Plate II. The northern folds were torn out along thrusts, culminating in a gigantic rupture called the Carmel Head thrust plane (marked "TT" in the section) traceable all across the Island, on which a great slice of the Mona Complex has been driven over Ordovician rocks in a southerly direction, for something like a score of miles. The pressure of these movements was often strong enough to squeeze out the softer minerals of the rocks, and thus to develop (see p. 20) a new series of divisional planes. Many of the shales accordingly tend to split, not along the original bedding, but along this, which is a true slaty cleavage, though usually a feeble one. But, unlike the great disturbances of the Mona Complex, it was rarely strong enough to induce crystalline metamorphism, which is only found locally, and even there is of a low order. The structures are, in this case also, of mountain-building type; yet of the mountains to which they gave rise, as of their greater predecessors, not a vestige now survives.

A Chemical Aftermath.—We have seen that the crystalline metamorphism which was produced was very slight. Yet chemical changes did follow, and of a somewhat singular kind. Heated waters, very much like those which to-day break out at the geysers of Iceland, were driven in among the rocks underground in various districts. In the course of their subterranean journeys, they took into solution large quantities of silica. This they could only dissolve when hot, so that as soon as they began to cool, it was obliged to return into a solid state. Therefore, at the places where it did so, the rocks became permeated with minutely granular quartz, like ice in the pores of a frozen sponge, which obliterated their slaty cleavage, and converted the once fissile shale into an intensely hard, grey, flint-like substance. At a slightly later stage of the process, the water occasionally brought sulphur-compounds of iron, copper, zinc and lead, which at one spot crystallised on a large scale along with vast quantities of silica. These (especially the copper) are the ores which have been mined at Parys Mountain.

The Devonian Period.

When the veil next lifts, we find that the mountainous region just alluded to had become reduced to a tract of rugged barren hills, between which there curved a long deep valley, gently sloping eastwards, and containing a large land-locked sheet of water. In this valley was accumulated some 1,300 feet of conglomerate, red sandstone, and calcareous wind-blown dust-rock. They rest upon the worn and upturned edges of the folded older rocks, and their conglomerates are full of pebbles of local members of the Ordovician and the Mona Complex. The climate was dry and desert-like, and no fossils have been found; but their position in the chronological succession (between the Silurian and the Carboniferous) together with the nature of the rocks, leave no doubt that they belong to that lacustrine phase of the Devonian system which is called the *Old Red Sandstone.* After their deposition, disturbances, of the same over-driving type as before, broke out again and folded them in the same manner as their predecessors, though far less powerfully.

The Carboniferous Period.

The Limestone Series.—Another long interval ensues, during which the highlands produced by the last disturbances were gradually reduced to a plateau, some 1,400 feet in height, sloping gently to an eastern sea. Except that the sea now lay to the east instead of the west, the conditions were singularly like those which we find (p. 10) at the dawn of Ordovician time. For subsidence began once more, and that sea crept slowly westwards. Banks of conglomerate, composed of water-worn fragments of the Mona Complex, the Ordovician, and other old rocks were spread out upon the upturned edges of those disturbed and oft-wasted formations. Subsidence continuing, open-sea conditions began to prevail, so that corals and other lime-secreting organisms were able to flourish in great numbers, and in this manner was accumuated the Carboniferous Limestone. That limestone series has lately been divided throughout the British Area, into six fossil zones. The subsidence just alluded to did not, however, admit the sea to our Area till the time-phases corresponding to the first four of those zones were over, so that only the fifth and sixth were deposited here. But the fifth is very finely developed, being 1,200 feet in thickness, and rich in marine fossils, especially in corals. On it rest 100 feet of curious flinty beds, with microscopic organisms, which belong to the sixth zone. By the time that its highest beds were slowly accumulating, the whole of our Area seems to have been submerged.

The Coal-Measure Forests and Lagoons.—Subsidence then received a check, the sea shallowed, and thick beds of sand were

laid down upon the flinty series. Deposition, in fact, outran subsidence, until the sea was silted up for many miles, and great mud-flats were formed, upon which forests grew up and flourished for ages. After this pause the land again went quietly down and the ruins of the forests were buried and compressed beneath a weight of new sediment. Thus was formed the first of the coal-seams. Subsidence and sedimentation continued, with twelve more similar prolonged pauses, each admitting of a growth of swampy forest. These make up the thirteen seams of the Anglesey coalfield. The Coal Measures accumulated in the course of this intermittent subsidence consist of some 1,500 feet of sandstone and shale, the total thickness of the thirteen coals being about 49 feet.

The shales adjacent to the coals have yielded 22 species of land plants, while those between the sandstones contain fish (mainly of the shark type) and shallow-water marine shells. From this rapid alternation of terrestrial and marine deposits we see how very little the great swampy forests can have stood above sea-level, for the least subsidence was sufficient to submerge them. Similar conditions are presented to-day by the mangrove swamps of tropical sea-boards.

A Desert Episode.—The Coal Measure conditions were brought to an end by some gently undulating earth-movements, which brought into being a wide land, whose hollows were filled with extensive shallow lakes. But this change was accompanied by a singular meteorological transformation, for the climatic conditions became those of a desert. Arid winds, just as in the wastes of Central Asia to-day, drove before them clouds of dust and sand, grinding and polishing the rocks, filling up the lakes and eventually burying the desolate valleys. In this manner were accumulated the barren red sandstones and purple dust-rocks known as "*The Red Measures.*" They rest upon a somewhat eroded surface of slightly disturbed Coal Measures; and are, in our Area, not less than 700 feet in thickness.

THE POST-CARBONIFEROUS DISTURBANCES.

Powerful disturbances, the last which have seriously bent and fractured the rocks with which we have dealt in this essay, then set in. But the over-driving tendency of the older movements is absent, the beds being thrown into broad curves of great size but gentle inclination. Breaking them are many vertical ruptures, the largest of which, called the Berw fault (marked FF in the section), has been traced all across the Island, and has a displacement of 2,300 feet. Doubtless these disturbances gave rise to land, but under the forces of erosion, it has, like its predecessors, long since disappeared.

The Mesozoic Submergence.

A great gap in the record now ensues, for no Mesozoic rocks have been found in the Island; though there is indirect evidence that considerable sheets of them were laid down upon our Area, but were worn away by Neozoic denudation. Most of the British region, it is well-known, gradually subsided in the course of the Triassic, Jurassic, and Cretaceous periods, until, during the deposition of the Chalk, not much remained above the sea. Beneath that sea our own portion of the region was overwhelmed.

Neozoic Times, and the Development of the Present Land-Surface.

Emerging from the long Mesozoic submergence, our Area became, during Eocene, Oligocene and Miocene times, part of a very extensive and somewhat lofty land.[1] During the Oligocene period, volcanic activity broke out on a gigantic scale in the Western Scottish and adjacent regions. Its energies found expression here also, but only in the injection of molten rock from below into some 30 subterranean fissures, wherein it cooled and crystallised without being able to reach the surface of that time. These dykes, which are of dolerite, are the last contribution in this region to the solid architecture of the earth-crust. But, conditions being persistently terrestrial, the rest of the work of Neozoic time in our Area was not accumulative.[2] It was erosive and destructive.

The Development of Our Present Land Surface.—At this stage, accordingly, the process began which eventually developed our existing Land Surface. Immense as is the time which that development has taken, it is as yesterday compared with even the latest of the sedimentary systems with which we have been dealing, not to mention that of the Mona Complex, for not a single feature of the present landscape was in existence until the Pliocene period; before which, indeed, the very word "Anglesey" would have been devoid of meaning.

The old highland of the earlier Neozoic periods, attacked by the remorseless atmospheric agencies, was gradually cut down, until, in Pliocene times, several hundred square miles of it had become reduced to a very low plain which seems to have been finally levelled off by the action of the sea. Rising

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[1] The region to the south, rising much higher, became the lofty block out of which has been sculptured the present mountain-land of Wales. It must not be forgotten, however, that the individual mountains thereof are wholly the work of the slow erosion which ensued.

[2] No Neozoic sedimentary rocks have been found, and none seem to have been deposited in our Area.

from it, however, to heights of some 300-400 feet, were nine isolated survivors of the older land. Then this plain, carrying the nine hills upon its back, was lifted and became a plateau some 270 feet in height, which (as it extends to the feet of the mountain-land) may conveniently be called "The Menaian Platform." Its outer parts were composed of relatively soft Mesozoic formations, but there was a hard nucleus of the Mona Complex and Palæozoic rocks, occupying some 400 square miles. Attacked, as it rose, by the surrounding sea, the outer parts were gradually cut away, but the process met with a check at the margins of the hard nucleus, whose disengagement from its environment established a relatively stable coast. This is the initiation of a country to which we can, for the first time in geological history, apply the name of "ANGLESEY."

Upon its even surface, in the meantime, a valley system was being incised and slowly deepened, so that, by the close of Pliocene time, subaerial decay and running water had sculptured from it the leading features of the scenery which still survives. No one can look at Anglesey without noticing how straight and even are the sky-lines of the ridges, which, viewed from a distance, melt into what seems an unbroken continuity. No matter what the varying nature of the rocks, no matter what the complexity of their structures, all are shaved off without any discrimination. In that mysterious feature we see the remains of the old Pliocene Menaian Platform.

Late Pliocene Anglesey, could we have walked in it, we should have found quite recognisable. We should have found the same even sky-line, the same principal valleys, the same bays and headlands of the coast, the same nine ghostly survivors of the older land.[1] Yet, in spite of this, nothing close around us would have been the same. In particular, we should have found that all the crags were much more sharp and angular than they are to-day. Nor should we, to enter the country, have had to cross any Menai Strait, though two long hollows might have told us when we were passing from Arvon into Mon. We should have known we were in Anglesey, yet with a pervading sense of strangeness.

THE PLEISTOCENE PERIOD AND THE GLACIAL EPISODE.

The climate of Pliocene times was genial, but an extraordinary change was at hand. Colder and colder grew the air, heavier and heavier the snow-fall, the distant mountains became snow-

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[1] Holyhead Mountain, Mynydd y Garn, Mynydd Eilian, the Hill of Nebo, Mynydd Bodafon, Mynydd Llwydiarth, Llanddona Common, Bwrdd Arthur. Owing to the 270 ft. uplift of the Menaian Platform, from which they rise, they are now some 500–700 ft. in height, measuring from sea-level.

clad all the summer long, till glaciers formed upon them, eventually filling the valleys to great depths, and creeping out on to the lowlands. But the glaciation of Anglesey was not their work. It was the work of a yet greater glacier, or rather ice-sheet, like those of present-day Greenland or Antarctica, which, gathering in the shallow basin of the Irish Sea, and totally displacing the sea-water, moved in a southerly direction. Mounting the old sea cliffs, it overwhelmed the whole of Anglesey beneath 1,700 ft. of slowly moving ice, and proceeded until, somewhere in the Menai country, it met and coalesced with the glaciers of the mountain-land. Mutual deflection ensued, imparting to the ice-sheet a south-westerly course, which has left unmistakable marks upon the surface of our country. It rounded off the north-eastern faces of the angular crags of Pliocene times, scored the rocks with grooves and scratches which point from north-east to south-west, and transported countless boulders in the same direction. During the preceding age of genial climate, the rocks had decomposed to considerable depths. The ice, grinding off these products of decay, dragging them out and compressing them, loaded the hollows with the smooth undulating sheets of tough boulder-clay, varying in thickness from a few inches, often to 30 ft., and sometimes to 100 ft., which are such a feature of our lower lands. The boulders of these clays, like the rocks of the sub-glacial floor, are commonly scratched and occasionally polished. Most of them are derived from local sources, but a considerable number have come from Cumberland and southern Scotland.

After a long time, the climate began to improve, the ice retreated, and its melting-waters deposited wide sheets of sand and gravel. Here and there, too, they cut out new channels. One such case is of great importance, for before the ice-sheet had completely parted from the glaciers of the mountain-land, their flood-waters, passing along the two old valleys of the Menai country which we have already mentioned, united them into a continuous trench. Its floor stood then above sea-level, but it made for the first time a clear demarcation of Mon from Arvon.

At last the ice disappeared altogether, leaving an Anglesey which, though bleak and bare, had the landscape features of to-day.

Anglesey in the Holocene Period.

As the country became once more habitable, Pleistocene conditions passed insensibly into those to which we are accustomed. There were numerous lakes, two of which were several miles in length; and there was a great extent of forest. Early Holocene Anglesey, however, was about 60 ft. higher and consequently somewhat larger than that of the late Holocene period wherein we live. Then, in the times of Neolithic man, ensued the

last of the many movements of the land; and the country, subsiding 60 ft., was reduced to its present elevation. This had several important consequences. One was that the sea, gaining easier access than before, has cut away some 30 square miles of boulder-clay. Another is that wrecks of the outer fringes of the Neolithic forest have been let down and preserved for us under the sands of our sea-bays. Finally, as the land went slowly down, the sea crept little by little along the already continuous hollow of the Menai country, until it became an open strait and Anglesey became an Island.

Conclusion.

In this brief essay, we have rapidly reviewed a vast series of successive changes. But the Anglesey we see to-day is not a final term. It is but one more passing phase. The same unresting and resistless forces which have brought it into being are, even while we gaze upon it, sweeping it away; and a time is, geologically speaking, not far distant, when it will have disappeared as utterly as have the vanished lands and seas whose place it occupies.

GLOSSARY OF TERMS.[1]

Boulder-Clay.—A product of the grinding of rocks by heavy ice-sheets. It is very tough and full of stones usually scratched and sometimes polished by the action of the ice when in motion.

Calcium.—The metal whose oxygen-compound is lime.

Calcareous.—Containing carbonate of calcium, the compound of calcium, carbon and oxygen.

Carbonaceous.—Containing uncombined carbon, the element which occurs as charcoal and coal.

Chalk.—A soft limestone (*see* "Limestone") which occurs in the Cretaceous System.

Chlorite.—A pale green shiny mineral, crystallising in thin flakes, and composed of oxides of silicon, magnesium and aluminium, with usually a little iron.

Conglomerate.—Old pebble-beds (of sea or river beaches); hardened by consolidation of the matrix or cementing material, which consists of sand or mud.

Denudation.—The wearing down of rocks, and consequent laying bare of once underlying rocks by atmospheric agencies, such as wind, rain, frost, rivers, glaciers and the sea.

Dolerite.—A crystalline igneous rock, composed of felspar, with minerals containing magnesium, calcium and iron.

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[1] This is arranged alphabetically, but should be used in the manner of cross-reference. For instance, under "Chlorite," *see* "Silicon" and "Oxides."

Dyke.—Igneous rock which has been forced up when molten into a fissure wherein it has cooled and consolidated.

Element.—A substance which has not yet been decomposed by what may be termed ordinary chemical methods.[1] All varieties of matter are composed of these elements in combination with one another or uncombined. Out of some 87 known elements; oxygen, silicon, aluminium, iron, calcium, magnesium, sodium and potassium (in order of abundance as here enumerated) make up about 98 per cent. of the accessible crust of the Earth.

Erosion.—The excavation of valleys by running water.

Fault.—A rupture, approximately vertical, along which rocks have been let down on one side and raised on the other.

Felspars.—Crystalline minerals, usually colourless, composed of oxide of silicon and aluminium, with oxides of calcium, sodium or potassium. Next to quartz, the felspars are the most abundant of all minerals.

Flint.—*See* "Silica."

Foliation.—*See* p. 9.

Glaciation.—The wearing down, rounding and scratching of rocks by ice.

Glacial Period.—Often called "The Ice Age." There was more than one, but the term is frequently understood to refer to that which occurred in the Pleistocene Period.

Glaucophane.—*See* "Hornblende."

Gneiss.—A highly crystalline rock, resembling granite, but with a parallel or banded structure.

Granite.—A plutonic igneous rock (*see* "Plutonic"). Usually composed of quartz, a felspar and a mica. Granites are rich in silicon but poor in magnesium and iron.

Graptolite.—*See* p. 11.

Hornblende.—A dark brown or green mineral crystallising in prisms, composed of oxides of silicon, aluminium, magnesium and iron. *Glaucophane* is a blue hornblende containing sodium.

Igneous Rocks.—*See* p. 2.

Lenticular.—Shaped like a lens, thinning out all round to an edge from a thicker centre.

Limestone.—Rock composed essentially of carbonate of calcium, whose crystalline condition is calcite.

Metamorphism.—The production of new structures and of new crystalline minerals in rocks, at great depths, under the influence of heat due to slow movement under heavy pressure.

Mica.—A lustrous mineral crystallising in thin flakes. The white micas are composed of oxides of silicon, aluminium and potassium. The dark mica contains magnesium and iron.

Mineral.—A substance of definite chemical composition (usually a compound, but sometimes an uncombined element) which occurs in the accessible crust of the Earth. Most minerals are crystalline. Out of more than 2,000 known species, only about 50 are important constituents of rocks.

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[1] It is impossible here to deal with recent researches into the disintegration of elements by subtle agencies such as radio-activity. For the purpose of this article, the elements may be regarded as simple substances.

Neolithic Man.—Man of the later stone-tool-making period (as distinguished from Palæolithic man, of the old stone-tool-making age).

Oxides.—The compounds of oxygen with other elements, whether non-metallic or metallic.

Plutonic Rocks.—Igneous rocks which have cooled slowly at great depths, thus acquiring a thoroughly crystalline texture. Those to which we have access have been subsequently exposed by denudation.

Potassium.—The metal whose oxygen compound is potash.

Quartz.—*See* " Silica." Quartz is the most abundant of all minerals.

Rock.—An aggregate of minerals.

Sandstone.—A rock consisting of small rounded grains of quartz (often with some felspar, mica and other minerals), derived by erosion from older rocks. It is an old sand, hardened by consolidation of the (usually muddy) matrix.

Schist.—*See* p. 9.

Sedimentary Rocks.—*See* p. 3.

Serpentine.—A plutonic igneous rock (*see* " Plutonic "), rich in magnesium and iron, but poor in silica. *See* p. 7.

Shale.—A consolidated mud-rock, generally occurring in thin layers, along which it splits readily.

Silica, Silicon.—Silica is a compound of oxygen and the non-metallic element silicon. Its crystalline condition is quartz ; its non-crystalline is flint.

Slate.—A modification of shale, which now splits independently of its original bedding-layers, along planes produced by pressure.

Sodium.—The metal whose oxygen compound is soda.

Spilite.—A lava allied to the dolerites, but rich in sodium. It often has a " pillowy " structure.

Thrust-plane.—A rupture on which rocks have been driven at a low angle to the horizon.

Volcanic rocks.—Molten matter which has flowed out from a volcano and consolidated on cooling in the open air or on a sea-floor (lava). Often it explodes on ejection into dust and fragments (volcanic " ash ").

Zone.—*See* p. 4.

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